Comparison of *Coptotermes formosanus* and *Coptotermes gestroi* (Blattodea: Rhinotermitidae) Field Sites and Seasonal Foraging Activity in Hawaii

by

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ABSTRACT

Field surveys were carried out from January 2010 to June 2011 to record the environmental properties of *Coptotermes formosanus* Shiraki and *C. gestroi* (Wasmann) (Blattodea: Rhinotermitidae) field sites on the island of Oahu, Hawaii; and to document seasonal patterns in *C. formosanus* and *C. gestroi* foraging activity. The two field sites selected differed in elevation, soil characteristics, vegetation, and mean temperature and humidity patterns. The *C. formosanus* colony was located on the Manoa campus of the University of Hawaii, near Miller Hall; while the *C. gestroi* colony was located 40 km away at the Barber's Point Horse Stables in Kalaeloa, Oahu (formerly Barber's Point Naval Housing). Mean temperature and humidity were recorded monthly at each field site using a Hobo® data logger (1000-1100h), soil samples were taken from each site and analyzed for physical properties, and vegetation type/s were observed, photographed, and samples brought to laboratory for identification. During each site visit, the number of active termite collection traps (termites present) out of a total of 22 traps per site were counted. The *C. gestroi* field site was generally warmer than that of *C. formosanus*. Both termite species exhibited irregular activity throughout the year, although *C. formosanus* was more active in general during cooler months (winter) than *C. gestroi*; while *C. gestroi* was generally more active during late spring and summer months. These results, as well as introduction histories, may help to explain *C. gestroi* distribution patterns in Hawaii.

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INTRODUCTION

The Hawaiian Islands are an archipelago of eight major islands in the North Pacific Ocean, formed by volcanic activity over a hotspot in the earth's mantle. The Hawaiian Island archipelago is the most isolated group of islands on earth. The islands have a climate typical of the edges of the tropical region, with temperatures ranging between 25^{0}C - 32^{0}C. The islands receive most of their rainfall from the trade winds during the winter months (October to April) (Ziegler 2002).

Eight introduced termite species have been recorded in Hawaii (Grace *et al.* 2002). Among them, the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Blattodea: Rhinotermitidae), was introduced over 100 years ago and is the most economically important and widely distributed insect pest in Hawaii (Tamashiro *et al.* 1987, Grace *et al.* 2002). In contrast, the more recently introduced Asian subterranean termite, *Coptotermes gestroi* (Wasmann), formally known as *Coptotermes vastator* Light in the Pacific (Yeap *et al.* 2007), has a very limited and localized distribution on the island of Oahu (Woodrow *et al.* 2001).

Of the drywood termites (Kalotermitidae), *Incisitermes immigrans* and *Neotermes connexus* are long-term residents of Hawaii that are only very rarely found in structural wood (Woodrow *et al.* 1999), and *Cryptotermes brevis* is the most severe drywood termite pest. *Cryptotermes cynocephalus* and *Incisitermes minor* have limited distributions on the island of Oahu (Grace *et al.* 2002). A rotten wood termite, *Zootermopsis angusticollis* (Termopsidae), is known to occur in the Kula region, on the island of Maui (Grace *et al.* 2002).

C. formosanus is primarily found in subtropical and temperate regions, whereas *C. gestroi* occurs largely in the tropics (Su 2003, Grace 2006). The distributions of these two species overlap in Florida (Scheffrahn & Su 2005), Taiwan (Shiraki 1909, Tsai & Chen 2003, Li *et al.* 2009), and Hawaii (Swezey 1914, Weesner 1965, Grace 2006). In Hawaii, *C. formosanus* is distributed throughout the island of Oahu (as well as other islands), while *C. gestroi* is currently limited to the southwest side of Oahu. *Coptotermes gestroi* appears to be expanding in distribution on Oahu relatively slowly (Uchima & Grace 2009; Grace, unpublished observations).

Uchima & Grace (2003a) estimated the foraging distance and foraging population size of two *C. gestroi* colonies on Oahu using the mark-release-recapture method. The two *C. gestroi* colonies were present in a residence in Kalaeloa, Oahu (formerly Barber's Point Naval Housing) and in the Barber's Point horse stables in Kalaeloa. They estimated the foraging population in the horse stables as 679,193±120,065 individuals, foraging area as 287.2m^2 and foraging termite biomass as 1.6±0.3 kg. The foraging population in the residence in Kalaeloa was estimated as 186,593±51,910 individuals, the foraging area as 10.5m^2 and the foraging termite biomass as 0.5±0.1kg. These results suggested that *C. gestroi* may have smaller colonies and foraging areas than *C. formosanus* in Hawaii.

The objectives of the present study were: (1) to record environmental properties of two field sites of *C. formosanus* and *C. gestroi* in order to obtain a basic idea of their comparative habitats; and (2) to document any seasonal variation in *C. formosanus* and *C. gestroi* foraging activity by checking field collection traps every month.

MATERIALS AND METHODS

Site Descriptions

The two field sites of the two different termite species on the Island of Oahu differ in elevation and temperature. For *C. formosanus,* we used a colony near Miller Hall on the Manoa campus of the University of Hawaii (21^0 17' N, 157^0 99' W; 23.47m above sea level; average rainfall 267.21cm; annual mean temperature 18.61^{0}C). For *C. gestroi,* we used a colony located 40 km from the Manoa campus, at the Barber's Point Horse Stables (Kalaeloa) (21^0 19' N, 158^0 02' W; 9.14 m above sea level; annual rainfall 53.09 cm; annual mean temperature 24^{0}C).

Field Surveys

Field surveys were carried out from January 2010 to June 2011. To document environmental properties and seasonal variations in termite activity, temperature and humidity at each site was measured monthly using a Hobo® data logger (1000-1100h), soil samples were taken from each site and analyzed for physical properties, and vegetation type/s were observed, photographed, and samples brought to laboratory for identification. During each monthly site visit, the number of active termite collection traps (termites present) was counted. Each site contained 22 wooden box-type termite aggregation traps, after the design of Tamashiro *et al.* (1973).

RESULTS AND DISCUSSION

We observed some differences in temperature, humidity, vegetation, soil types and soil water content at the two field sites (Table 1). At Kalaeloa (*C. gestroi* field site), there were a few thorny shrubs (most of the time very dry), high silt content in the soil, low soil water content and relatively high temperature. The *C. formosanus* field site at the University of Hawaii at Manoa had some vegetation (most of the time wet), low silt content in the soil compared to Kalaeloa, relatively high sand content, high soil water content and a relatively lower temperature than the Kalaeloa field site.

Many studies have correlated climatic variables such as minimum and maximum temperatures and annual rainfall to the range limits of species (Jeffree & Jeffree 1996, Bullock *et al.* 2000). Our study presents preliminary data regarding climatic variation between two termite habitats that may help to explain the differences in their distribution on Oahu. *Coptotermes gestroi* currently has a very limited distribution on the southwest side of Oahu, a region with high temperatures year-round. In temperature, this region may be similar to their natural tropical environment. Arntzen & Themudo (2008) found that geographical variations in ecological parameters determine the range limit of species. Subtropical *C. formosanus* is essentially found throughout Oahu, except in high forested areas. According to the research of Grace *et al.* (2004), *C. formosanus* colonies may extend large distances by making wider, relatively unbranched, and longer tunnels in the soil than *C. gestroi.* Also the foraging area of *C. formosanus* colonies appears to be larger than that of *C. gestroi* in Hawaii (Uchima & Grace 2003a) and *C. gestroi* colonies may be behaviorally constrained by the presence of *C. formosanus* in the immediate area (Uchima & Grace 2009). Uchima & Grace (2003b) also found that the feeding rate of *C. formosanus* was higher than that of *C. gestroi*. Hence, for these various reasons, as well as the history of their introductions, *C. formosanus* exhibits a much broader distribution than *C. gestroi* on the island of Oahu.

We also observed differences in seasonal activity between *C. formosanus* and *C. gestroi* (Fig. 1). We did not observe any regular pattern of foraging activity (number of active traps) with either species. In the case of *C. formosanus,* however, the greatest number of active traps was observed during winter (December 2010), and it was 13 out of 22 traps. The lowest number

Table 1: Environmental properties of the two field sites (Soil separation test; Sand (0.05mm), Silt (0.002-0.005mm) and Clay (0.002 or less).

Species/ Field site /Area	Vegetation	Soil type/s	Soil water content	Mean Annual Temperature (°C)	Mean Annual Humidity (%)
C. gestroi Kalaeloa 246.75 m^2	*Prosopis pallida* (kiawe tree), *Asystasia gangetica* (Chinese violet)	Sand 4.7%, Silt 52%, Clay 14.1%	6.33%	29.81	55.23
C. formosanus Miller Hall 28.6 m^2	*Asystasia gangetica* (Chinese violet), *Murraya paniculata* (mock orange)	Sand 6.7%, Silt 26.7%, Clay 6.7%	23.66%	26.58	63.64

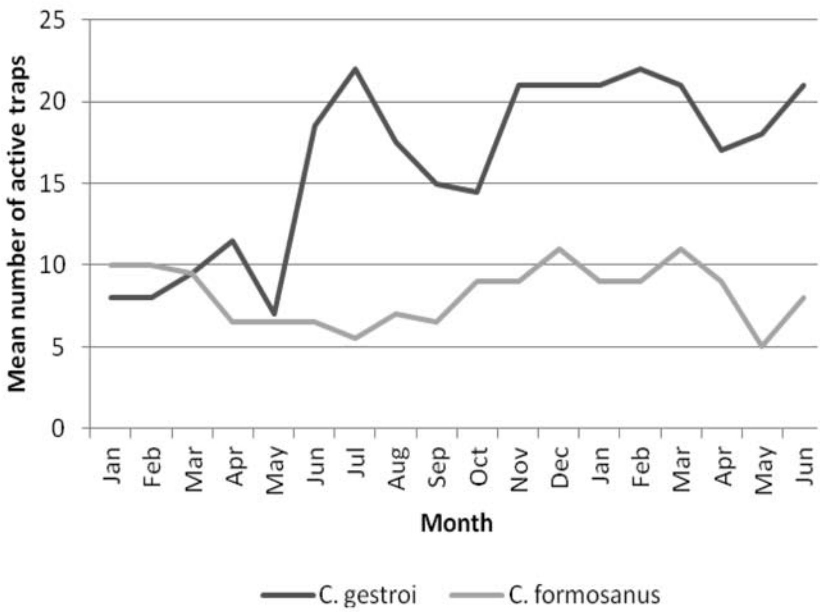

Fig. 1. Mean number of active collection traps (out of 22 traps per site) at *C. formosanus* and *C. gestroi* field sites on Oahu, Hawaii, plotted against month from January 2010 –June 2011.

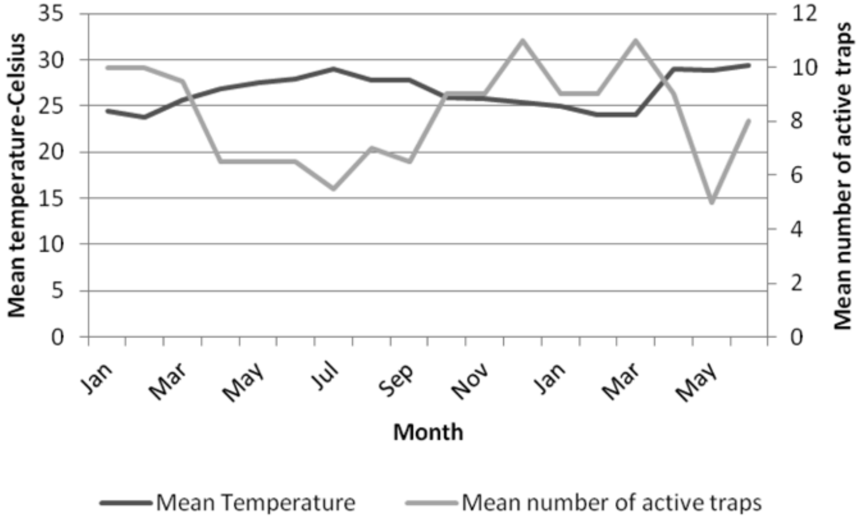

Fig. 2. Mean number of active collection traps (out of 22 total) at the *C. formosanus* field site in comparison to mean temperature from January 2010 –June 2011.

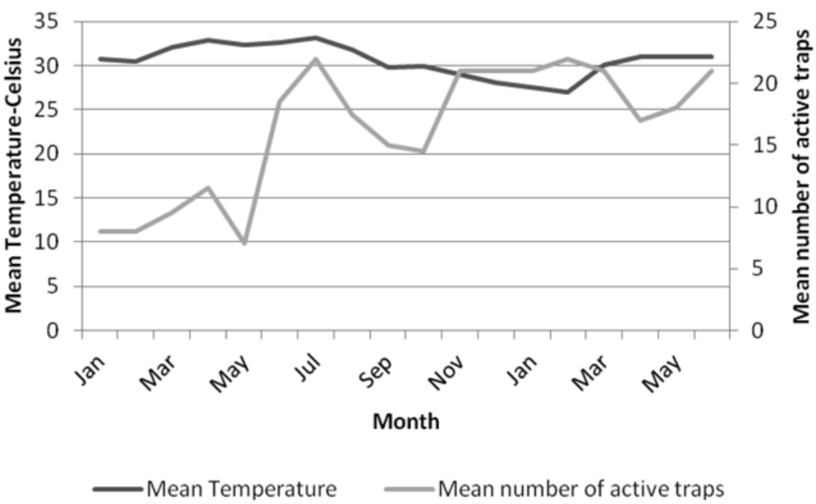

Fig. 3. Mean number of active collection traps (out of 22 total) at the *C. gestroi* field site in comparison to mean temperature from January 2010 –June 2011.

of active traps (5 out of 22) was observed during summer (July 2010 and May 2011). From January to March 2010 and from October 2010 to March 2011, *C. formosanus* showed a peak activity from 9 - 13 active traps. On the other hand, *C. gestroi* had greatest activity during summer (July 2010) and spring (February 2011) (all 22 traps active). The lowest active trap number recorded for *C. gestroi* was 7 in January and May 2010. The peak activity periods for *C. gestroi* were July 2010 and November 2011, with the number of active traps ranging from 21-22.

Fei & Henderson (2004) reported that temperature and moisture were the most important factors in the distribution of subterranean termites. Bouillon (1970) found that seasonal variations are directly correlated with termite foraging activities. Buxton (1981) also noted that the number of termites in the colony, the production of new individuals and the amount of food already stored in the nest fluctuated according to the season. In contrast, however, Dawes-Gromadzki & Spain (2003) found no direct relationships between rainfall and termite species richness, or frequency and intensity of attack on baits during a field investigation of seasonal patterns in the activity and species richness of surface-foraging termites at paper baits in a tropical Australian savanna.

Throughout the experimental period (from January 2010 to June 2011) there were fluctuations of temperature and relative humidity at both field sites. Temperature was relatively steady, however, in comparison to relative humidity. At the *C. formosanus* field site, temperatures ranged from 23 ^{0}C to 30 ^{0}C; however, for *C. gestroi* it ranged from 27 ^{0}C to 33 ^{0}C (Figures 2 & 3). At the *C. gestroi* Kalaeloa field site, relative humidity ranged from 46% to 70%; whereas at the *C. formosanus* Miller Hall site it ranged from 51% to 80% (Figs. 4 & 5).

In conclusion, the *C. gestroi* field site was generally warmer than that of *C. formosanus*. Both termite species exhibited irregular activity patterns (as represented by the number of active termite collection traps) throughout the year, although *C. formosanus* was more active in general during cooler months (winter) than *C. gestroi*; while *C. gestroi* was generally more active during late spring and summer months. It is worth pointing out that both subterranean termite species distributions and the territory sizes exhibited by individual termite colonies may change in the future as a result of global climate change,

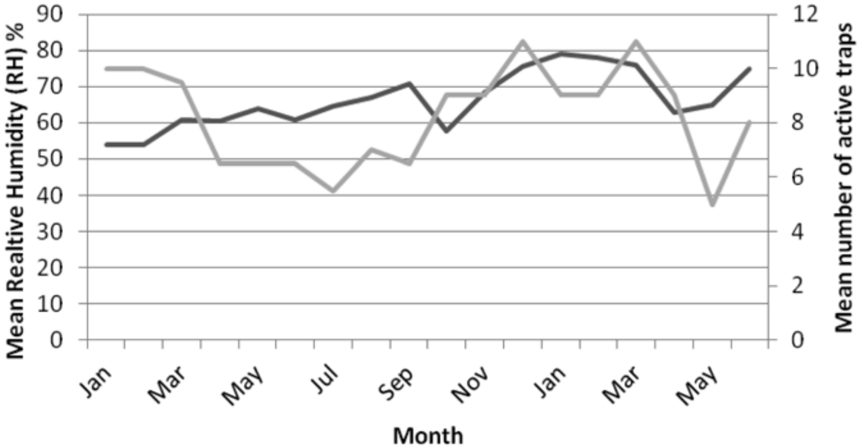

Fig. 4. Mean number of active collection traps (out of 22 total) at the *C. formosanus* field site in comparison to mean relative humidity from January 2010 –June 2011.

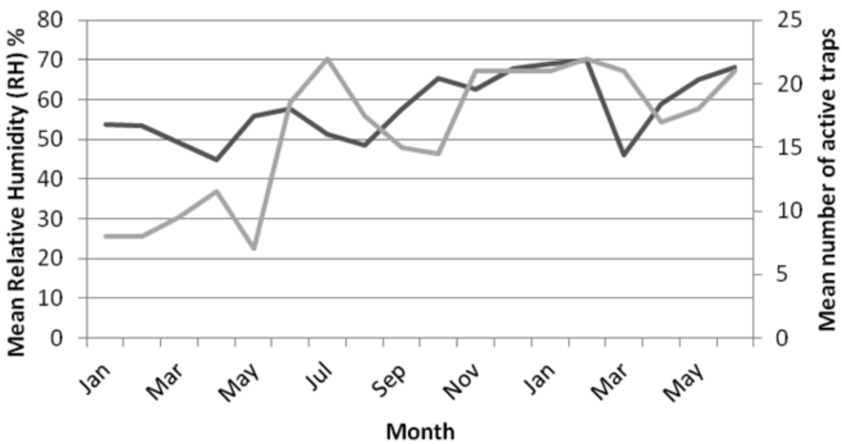

Fig. 5. Mean number of active collection traps (out of 22 total) at the *C. gestroi* field site in comparison to mean relative humidity from January 2010 –June 2011.

as recently modeled by Lee & Chong (2011). However, different temperature preferences as well as different histories of introduction may help to explain both the current limited distribution of *C. gestroi* in Hawaii, and eventual limits to its future distribution in the islands.

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